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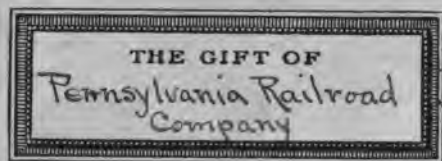
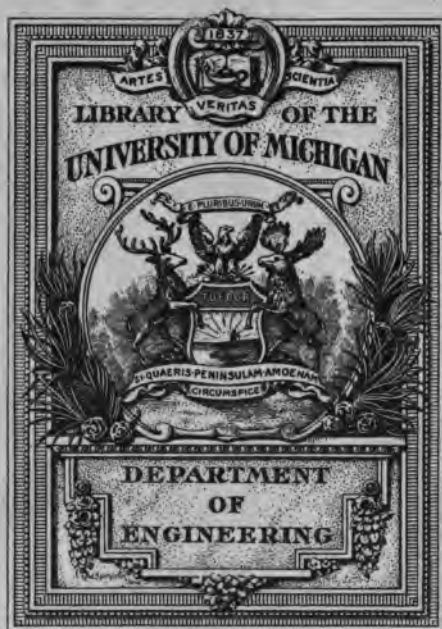
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The Pennsylvania Railroad Company  
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The Pennsylvania Lines West of Pittsburg.

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LOCOMOTIVE TESTING PLANT

AT THE

LOUISIANA PURCHASE EXPOSITION,

St. Louis, Missouri, U. S. A.

1904.

44

**The Pennsylvania Railroad Company.  
The Pennsylvania Lines West of Pittsburg.**

**LOCOMOTIVE TESTING PLANT.**

AT THE

**LOUISIANA PURCHASE EXPOSITION.**

**ST. LOUIS, MISSOURI, U. S. A.**

**1904.**

**BULLETIN No. 1.**

**ORGANIZATION, PLAN AND SCOPE.**

**ORGANIZATION :**

**The Pennsylvania Railroad System:**

J. J. TURNER, Third Vice President, Pennsylvania Lines West of Pittsburg.

THEO. N. ELY, Chief of Motive Power, Pennsylvania Railroad System.

F. D. CASANAVE, Special Agent, Pennsylvania Railroad System.

E. D. NELSON, Engineer of Tests, Pennsylvania Railroad Company, Altoona, Pa.

**Louisiana Purchase Exposition.**

WILLARD A. SMITH, Chief of the Department of Transportation Exhibits, Louisiana Purchase Exposition.

**ADVISORY COMMITTEE :**

**On behalf of the American Society of Mechanical Engineers.**

W. F. M. GOSS, Dean of the Schools of Engineering, Purdue University.

EDWIN M. HERR, General Manager, Westinghouse Air Brake Company.

J. E. SAGUE, Mechanical Engineer, American Locomotive Company.

**On behalf of the American Railway Master Mechanics' Association.**

F. H. CLARK, Superintendent of Motive Power, Chicago, Burlington and Quincy Railroad.

C. H. QUEREAU, Superintendent of Shops, New York Central and Hudson River Railroad.

H. H. VAUGHAN, Assistant Superintendent of Motive Power, Lake Shore and Michigan Southern Railway.

**OFFICERS :**

F. D. CASANAVE, Special Agent of the Pennsylvania Railroad System.

W. F. M. GOSS, Chairman of the Advisory Committee.

H. H. VAUGHAN, Secretary of the Advisory Committee.

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## INTRODUCTION.

The formal announcement of the purpose of the Pennsylvania Railroad System to provide the facilities for testing locomotives at St. Louis was made before the Conventions of the American Society of Mechanical Engineers and of the American Railway Master Mechanics' Association, June 25th, 1903. It happened that both of these organizations were then in session at Saratoga, and identical communications were addressed to each, except as to the names of the organizations involved. The communication which was received by the Master Mechanics' Association was as follows :

“TO THE AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION :

“The Pennsylvania Railroad System has arranged with the Universal Exposition of 1904, at St. Louis, to install as a portion of its exhibit in the Department of Transportation, a locomotive laboratory, to be built upon the most approved designs, and to be operated during the seven months of the exposition for testing locomotives.

“The entire exhibit, including the locomotive laboratory, will be in charge of Mr. F. D. Casanave, Special Agent, who is authorized to act for the Pennsylvania Railroad System in all matters pertaining thereto.

“It is the desire of the Pennsylvania Railroad System, as well as of the Exposition, that the series of tests to be conducted shall be upon the highest scientific basis, and the effort will be made to obtain results which will be of permanent value. The details of the plan have not yet been fully perfected, but it is expected that a large number of the most recent designs of American and European locomotives will be carefully and thoroughly tested.

“In order that the best results possible may be attained, it has been decided to ask your honorable body and the American Society of Mechanical Engineers, each to appoint an Advisory Committee of three members. The Pennsylvania Railroad System will provide all necessary apparatus and the force of engineers necessary to conduct the tests. It is desired that the Advisory Committee shall assist in laying out the programme of tests, and in making the plans that are necessary to secure the most important and most reliable results. You are requested to appoint such a Committee, and to appoint men who will be able and willing

to give the necessary time and study to the subject. It is important that the plans should be effected at the earliest date possible, in order to secure the hearty and full co-operation of the railroad companies and the locomotive builders, both in this country and in Europe.

"It is our intention to ask the General Commissioners of the principal European countries to appoint each a mechanical engineer of high standing to represent those countries on the Advisory Committee.

"For the Pennsylvania Railroad System :

"J. J. TURNER, Third Vice President, Pennsylvania Lines West of Pittsburg.

"THEO. N. ELY, Chief of Motive Power, Pennsylvania Railroad System.

"For the Universal Exposition, St. Louis, 1904 :

"WILLARD A. SMITH, Chief, Department of Transportation Exhibits, Louisiana Purchase Exposition."

Having received this communication and after some discussion, expressing the appreciation of members of the importance of the plans thus outlined, the following resolutions were offered and adopted :

"Whereas, This Association has been informed by the Pennsylvania Railroad Company that it will erect at the World's Fair, St. Louis, 1904, a complete laboratory for the testing of locomotives, at which it contemplates making full tests of locomotives of various types, as well as special appliances pertaining to locomotives, and

"Whereas, The Pennsylvania Railroad Company has invited this Association to appoint three of its members to advise and consult in the carrying out of this project ; be it

"Resolved, That the President of this Association be authorized to appoint, after conference with the Pennsylvania Railroad Company, three members of this Association to act as an Advisory Committee to the Pennsylvania Railroad Company, in matters relating to the testing of locomotives at the laboratory, which that Company is to install in the Transportation Building of the Louisiana Purchase Exposition, St. Louis, during the seven months from May 1st to December 1st, 1904; and be it further

"Resolved, That the thanks of this Association be tendered



to the Pennsylvania Railroad Company for giving the members of this Association the opportunity of participating in the investigations outlined in the preceding resolutions."

Similar action was taken by the American Society of Mechanical Engineers, and announcement was made of the appointment of Committees provided for by these resolutions, as follows :

By the American Society of Mechanical Engineers : Messrs. W. F. M. Goss, Edwin M. Herr and J. E. Sague.

By the American Railway Master Mechanics' Association: Messrs. F. H. Clark, H. H. Vaughan and C. H. Quereau.

On the same day, in response to a call issued by Mr. Casanave, there assembled at the Grand Union Hotel, Saratoga, a considerable number of gentlemen for an informal conference. There were present, beside Mr. Casanave and the Honorable Willard A. Smith, all the members of the Joint Committee, excepting Mr. Sague ; representatives of the technical press, including Mr. G. M. Basford, of the "American Engineer," Mr. William Forsyth, of the "Railway Age," and Messrs. Charles Ducas and C. H. Fry, of the "Railroad Gazette." The locomotive builders were represented by Mr. A. J. Pitkin, of the American Locomotive Company. Regret was expressed that no representatives of other locomotive works were for the time being within call.

The purpose of the meeting having been stated by Mr. Casanave, there was a generous interchange of views, leading to conclusions which, in some cases, have given definite shape to paragraphs in the programme which follows.

At the conclusion of this conference there was a formal meeting of the Joint Committee of Mechanical Engineers and the Master Mechanics, an organization being effected by the election of W. F. M. Goss, Chairman, and H. H. Vaughan, Secretary. After considering certain details entering into the work of the Joint Committee, the Chairman was appointed a sub-committee to draft a detailed programme for the guidance of all concerned. This having been duly prepared and having since been submitted to members for their criticisms, is now presented, as amended, with the approval of the Committee and of the Pennsylvania Railroad System, as constituting a programme which shall govern the further progress of the work.

## PLAN AND SCOPE.

The Pennsylvania Railroad Company will design and cause to be constructed a suitable plant for testing locomotives, and, in co-operation with the Department of Transportation Exhibits, will install the same at St. Louis. The plant will be ready for preliminary running by the first of March next, and in perfect running condition by the first of May, at which time formal work will commence. The purpose of the whole work is to be comprehensive and the endeavor will be to determine by the use of locomotives presenting different characteristics, the effect of the latter upon the economic performance, and the limits of the tractive power and boiler capacities.

The Pennsylvania Railroad System will organize and maintain, under the direction of its Engineer of Tests, a staff of laboratory attendants and computers, to the end that the plant and the locomotives thereon may be safely and properly operated and the experimental data promptly handled. It will also provide supplies of fuel and oil and will meet all other fixed charges incident to the progress of the work.

The Pennsylvania Railroad System, having called to its aid an Advisory Committee to assist in all matters of scientific interest, will in consultation with this Committee make selection of locomotives to be tested, determine conditions under which tests are to be run, specify as to the observations to be taken and the methods to be employed, and determine the manner in which the data shall be handled and the form in which the final results shall be presented.

**THE ADVISORY COMMITTEE.** While the communication of the Pennsylvania Railroad-System, in response to which the members of this Committee were appointed, clearly contemplates additions to the membership of the Committee, those already appointed have organized, and have been required to act in formulating the provisions of this programme. To avoid confusion, therefore, those named on page 3, will be regarded as "Members" of the Advisory Committee. Foreign representatives and others who may be hereafter appointed will be designated as "Affiliated Members."

Members and Affiliated Members of the Advisory Committee shall have voice and vote alike.

The Advisory Committee will devote such time as may be necessary to the general plan of the work, and may be called together at any time by the Chairman, or by an authorized representative of the Pennsylvania Railroad System.

**THE TESTING PLANT.** The details of this plant are now being worked up by the Pennsylvania Railroad Company. It is to consist of supporting wheels upon which will be carried the drivers of the locomotives to be tested, with friction brakes on the shafts of the same, a registering dynamometer of 80,000 pounds capacity, to which the drawbar of the locomotive will be attached, together with all necessary accessory apparatus for operating the plant and obtaining the desired data therefrom. As soon as practicable it is intended to issue a bulletin which shall completely describe and illustrate the details of the plant.

**LOCOMOTIVES TO BE TESTED.** In selecting locomotives for test, an endeavor will be made to secure variety in the essential principles of design. Since the time is necessarily limited, no considerable attention will be given in attempts to analyze the action of minor details. On the contrary, the effort will be to establish the economic performance of a number of typical locomotives when operating under a wide range of conditions.

No locomotive or type of locomotives will be acceptable, the value of which has not been proven by successful service on the road.

Locomotives to be acceptable must have weight and power which will make them comparable in these respects with the modern American machine. It is proposed to test no locomotive which has less than 2000 feet of heating surface in its boiler, excepting that in case of locomotives having superheaters the superheating surface may be regarded as heating surface, and in the case of locomotives having *Serve* tubes, credit for the surface of the ribbing will be allowed.

The gauge of the supporting wheels will be 4 feet 8½ inches, or the same as the standard gauge of American railroads, and the gauge of the locomotive offered for test must be such as to run safely thereon.

It is planned to test twelve different locomotives, and it is hoped that a portion of this number can be of foreign design and construction. The time to be allowed to each locomotive will vary from twenty to fourteen working days the longer time

being allowed those which are tested early in the season when both men and equipment will be new to the work. The intervals proposed are as follows :

1904.

1. May 2nd to May 23rd, inclusive.
2. May 24th to June 13th, inclusive.
3. June 14th to July 1st, inclusive.
4. July 2nd to July 19th, inclusive.
5. July 20th to August 5th, inclusive.
6. August 6th to August 22nd, inclusive.
7. August 23rd to September 7th, inclusive.
8. September 8th to September 23rd, inclusive.
9. September 24th to October 10th, inclusive.
10. October 11th to October 26th, inclusive.
11. October 27th to November 11th, inclusive.
12. November 12th to November 30th, inclusive.

It is not possible at this time to present a complete list of the locomotives which will be tested, but this is now under careful consideration and will be announced in a later bulletin.

It is considered advisable that the owner of each locomotive presented for test should furnish a man thoroughly familiar with its working to look after the lubrication, and in general render such assistance as will insure the tests being run without interruption.

The owner should also, if found necessary, provide a man thoroughly familiar with the mechanical details of the locomotive, who can advise in regard to any repairs that may be necessary during the series of tests.

**FUEL.** The Pennsylvania Railroad Company will supply for all participants two grades of coal of high quality, one an anthracite and the other a bituminous. The quality of each of these grades will remain unchanged throughout the progress of the work. This composition will be approximately as follows :

	ANTHRACITE.	BITUMINOUS.
Volatile matter, including water,	8 per cent.	20 to 22 per cent.
Fixed carbon,	86 " "	69 to 74 " "
Ash,	6 " "	9 to 6 " "

**FIREMEN.** The Pennsylvania Railroad Company will supply men whose experience on the road will have been supplemented by special training for their work upon the testing plant. Unless otherwise arranged, these men will fire all locomotives under test. Exhibitors may, however, furnish one of their own men to give necessary instructions to the regular firemen.

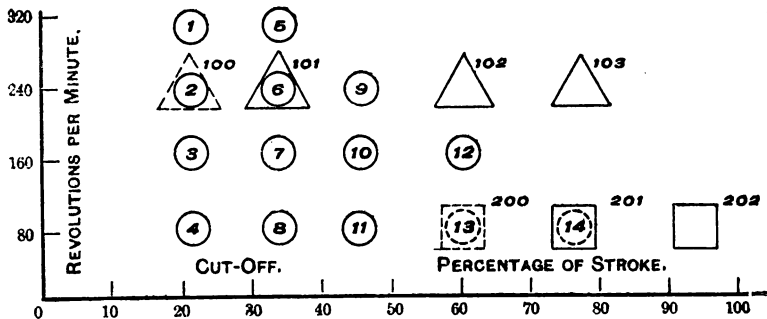
**THE TESTS.** It is proposed to make from sixteen to twenty formal tests of each locomotive put upon the plant, these to be preceded by one or more preliminary runs for the purpose of checking the valve setting, and of proving all accessory apparatus.

Each formal test will involve a run of approximately 100 miles, and throughout its duration the speed, load, steam pressure and other conditions of running will be maintained as nearly as possible, constant. The conditions represented by the several tests upon each locomotive will be so chosen that the results will fall into sets, and when so plotted will serve to disclose the performance of the locomotive under the full range of speed and cut-off for which it can be properly worked. The conditions which have been chosen for the formal tests are set forth diagrammatically by Figs. 1 and 2.

#### CONDITIONS OF RUNNING.

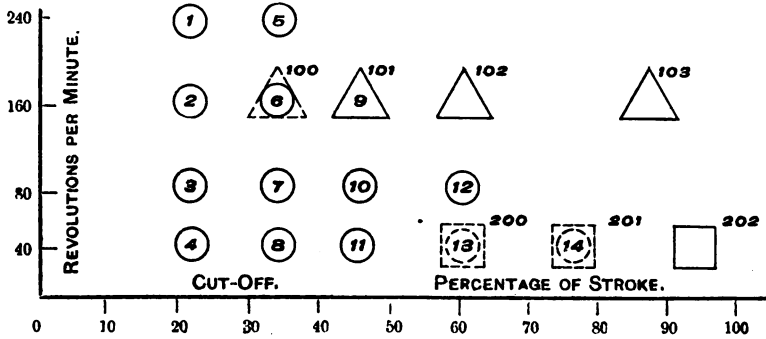
- = TESTS UNDER FULL THROTTLE.  
 □ = TESTS AT MAXIMUM ADHESION.  
 △ = THROTTLE TESTS.

FIG. 1. SIMPLE PASSENGER LOCOMOTIVES.



COMPOUND PASSENGER LOCOMOTIVES will be tested under conditions which are comparable with those specified for simple locomotives.

FIG. 2. SIMPLE FREIGHT LOCOMOTIVES.



COMPOUND FREIGHT LOCOMOTIVES will be tested under conditions which are comparable with those specified for simple locomotives.

Referring especially to figure 1, the circles show the speed and cut-off at which it is proposed to run the tests under a fully open throttle. Tests 1 to 4 represent a set at constant cut-off under speeds varying from 80 to 320 revolutions, the cut-off for these tests to be about 20 per cent. of the stroke. All tests of this set will be well within the capacity of the locomotive. Tests 5 to 8, inclusive, represent a second set, the cut-off for which will be made such as to make the power for test 5 the highest which can be developed at a speed of 320 revolutions. A third set at longer cut-off is made up of 9, 10 and 11. In this case the cut-off of the set is to be made such that No. 9 will give the maximum power which can be developed at a speed of 240 revolutions. Similarly, test 12 is to be made at such a cut-off as to demand the full power of the boiler at a speed of 160 revolutions, and with it will be grouped test No. 13, provided the adhesion of the drivers will permit a fully open throttle under so long a cut-off.

In case test 13 can be run, then another at a still longer cut-off, as, for example, test 14 at a speed of 80 revolutions, will be attempted. It will be apparent that tests under conditions thus chosen cover the entire range under which the locomotive may be operated with the throttle wide open. Thus, at any particular speed, an attempt to use the longer cut-off would result in a failure of the boiler to supply steam, or possibly, at the slowest speed, in the slippage of drivers. Similarly, at any particular cut-off, an attempt to operate at a higher speed would result in a failure of the boiler to supply steam. By combining the results the effect

of either changes in speed or changes in cut-off in the performance of the locomotive can be readily shown.

To determine the performance of the locomotive under varying throttle openings the series 100, 101, 102 and 103 will be run. This series will be at a constant speed. The power for all tests and, consequently, the drawbar pull will be constant and will be the same as that developed under a wide open throttle in test 2. For test 101 the cut-off is lengthened and the throttle closed sufficient to make the power the same as when with the shorter cut-off the throttle was wide open. Test 102 is at a still longer cut-off, for which the throttle will be still further closed, and test 103, the longest cut-off and the throttle of the least opening for the series. It is evident that the results of this series will show the relative performance of the locomotive in doing a given amount of work under a varying degree of throttling.

Tests 200, 201 and 202 are under starting conditions. The speed of all is to be the same. For test 202 the reverse lever is to be in its extreme forward position, and the throttle opening as wide as can be allowed without danger of slipping the drivers. Test 201 is with a shorter cut-off and wider opened throttle, and test 200 with a full open throttle.

It should be evident from the explanation which has been given that the diagrams Figs. 1 and 2, do not attempt to show the actual cut-offs which will be experimented upon, nor the precise number of tests which will be necessary to define the performance of a locomotive, but rather the principles which will underlie the selection of conditions, and the relation which the several tests bear each other. The limits of performance will be different for different locomotives, and one of the tests will be to establish values for these limits.

The several speeds employed for all passenger locomotives will be those set forth in Figure 1, so that the data for the several different locomotives will be strictly comparable.

The conditions under which freight locomotives will be tested will involve the several speeds given in Figure 2. A comparison will show that while the range of speed for the freight locomotive is lower than that fixed for the passenger locomotive, the two sets of conditions supply ample opportunity for the inter-comparison of results which may be obtained from the two classes of locomotives.

The conditions specified for testing compound locomotives are necessarily more general than those with reference to simple locomotives, since it does not appear that any single diagram can be made which will serve to define the conditions of running with reference to compounds. For example, some of the compounds submitted for test may be of such design that a single movement of the reverse lever will change the cut-off in both the high pressure and low pressure cylinder (or cylinders). Others may be so arranged that the cut-off remains constant on the low pressure cylinder until after that upon the high pressure cylinder has been reduced to half stroke, and still others may have the control of the high pressure cut-off quite independent of that of the low pressure cut-off. No simple statement as to cut-off, or even as to number of expansions, will have the same force when applied to locomotives of these different types. Again, some of the locomotives may have no provision for using high pressure steam in the low pressure cylinder, while others may be equipped with a by-pass for use at low speed. Obviously, machines thus designed should be tested with the by-pass in use, as well as without it.

In view of these facts, it seems wise in case of compound locomotives, to reserve a specific statement of the conditions which are to prevail until the characteristics of each locomotive to be tested are known. The conditions which will then be proposed will be submitted to each exhibitor interested, for criticism, and finally for approval.

In the meantime, it can be said that compound locomotives will be tested under conditions which are comparable with those specified for simple locomotives. The speeds will be the same and the several tests for each speed will be under such conditions of cut-off as will disclose the performance of the locomotives under a similar range of action. The conditions to be specified for each compound locomotive will have due regard for peculiarities in its design, to the end that the power and efficiency of each machine may be demonstrated under all conditions of running which may have been contemplated in its design.

METHODS TO BE FOLLOWED IN RUNNING A TEST. In preparation for a test, the locomotive will be started and gradually brought to the conditions of running which are to prevail throughout the test. When these conditions have been secured the preliminary running of the locomotive will be continued until the rate of firing becomes uniform and until all portions of the locomotive.





have become warmed to their work. When these conditions have been secured two strokes of a bell will give a preparatory signal. Thirty seconds later a single stroke of the bell will mark the beginning of the test. Upon this stroke all water levels will be observed, the ash pan cleaned and all observations taken, and thereafter all water and fuel used will be taken from a weighed supply. Throughout the test all conditions of running will be maintained as nearly constant as possible, observations being taken on the stroke of the gong at ten minute intervals. The duration of the test will vary from two to six hours, depending upon the rate of speed and load. The element of control in fixing the length of the heavy power test will be the amount of water evaporated, no test being ended until the evaporation equals thirty pounds for each square foot of heating surface. The lighter power tests may end after from four to six hours.

A test will be ended as it began. The fire which, throughout the test will have not changed greatly in its condition, will be brought as nearly as possible to the condition it had in the beginning, the ash pan will be cleaned, the water level in the boiler will be made to agree with that of the beginning of the test, and upon signal the final observations will be taken, and the use of water and fuel from a weighed supply will cease. As soon as practicable after this the locomotive will be stopped, the front end cleaned, and the data of the test collected and made of record.

A test will be started not earlier than 8 o'clock on each day, and when the conditions are such as will permit them to be of short duration, two tests may be run on the same day.

To avoid chances for error all important observations will be taken in duplicate by the use of independent instruments and observers. For example, the feed water will be metered and afterwards weighed, the weighings constituting the real record, and the readings of the meter the check record. The speed will be indicated by a Boyer or other speed indicator, and also by a counter which will register the revolutions, the latter supplying the real record, and the former the check record. Pressures will be observed from dial gauges, and registered by a Bristol recording gauge, the observed pressures constituting the real record; the recorded pressures the check. A separate indicator will be used on each end of each cylinder.



The smoke discharge above the locomotive will be so arranged as to entrap all solid matter or "sparks" passing out of the top of the stack. A chemical analysis will be made of the coal employed for each test, and of the smoke-box gases.

In the case of locomotives designed with special reference to the balance of reciprocating parts, and in the case of others, the performance of which may contrast with them, an effort will be made to study the motion (rocking, nosing, etc.,) of the locomotive as a whole while running at speed, in the hope that a definite relation will be found between the motion of the locomotive and its condition of balance.

In the case, also, of certain locomotives which will be selected with reference to their type of boiler, an effort will be made to secure a record of the direction and activity of the water currents circulating within several portions of the boiler when the latter is delivering steam, and especially of the cooler currents discharged from the injectors.

There will be obtained for each test, by direct observation, the following facts :

- Position of reverse lever.
- Position of throttle.
- Revolutions per minute.
- Total revolutions.
- Pounds of coal fired.
- Pounds of non-combustible material collected in ash pan.
- Pounds of sparks passing out of the top of the stack.
- Time when one or both injectors are in action.
- Pounds of water weighed to injectors.
- Pounds of water lost by injector overflow.
- Record of calorimeter giving quality of steam in dome of boiler.
- Indicator cards from each end of each cylinder, and from the valve box on one side.
- Drawbar stress as shown by dynamometer.

Pressures as follows :

- Of steam in boiler.
- Of steam in branch pipe leading to cylinder.
- Of air in the laboratory (barometric pressure).
- Of air in ash pan.

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